

Print Name (last name,first name): _____ | _____ |

Section: _____

Instructor: Circle one

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DIRECTIONS

(PUT AWAY YOUR CELL PHONE. IF YOU ARE CAUGHT USING A CELL PHONE, SMART WATCH OR PDA YOU WILL BE EJECTED FROM THE EXAM IMMEDIATELY AND GIVEN A ZERO. TALKING IS NOT ALLOWED DURING THE EXAM. IF YOU MUST GET UP, PLEASE RAISE YOUR HAND AND TELL THE PROCTOR FIRST.)

1. First fill in the information at the top of this paper. Print your last name as it appears on the class roster, then print your first name and middle initial. Then read and sign the integrity code statement below. Finally fill in the requested information on the **SCANTRON ANSWER SHEET** according to the following scheme:

NAME: Print **LAST** name, then first (print clearly)SUBJECT: **Course and section**DATE: **10/04/2021****PERIOD: Your Student Number.**

2. The last page of this exam is a periodic table. It also has a list of several important constants. You may carefully remove this last page, if you choose, but do not open the staple.

3. This exam consists of three parts, A and B and C. **PART A** has 20 multiple choice questions worth five points each for a total of 100 points. Part B has 5 multiple choice questions with a higher level of complexity each worth 7 points for a total of 35 points. In both parts, each question has only one correct answer, and no credit is lost if you choose a wrong answer. Therefore, leave no question unanswered, even if you simply must guess.

4. **PART C** consists of open ended problems worth 40 points. Show all work, including how units cancel to give the final answer, along with appropriate sig. figs. Write your final answers in the spaces provided.

INTEGRITY CODE STATEMENT: On my honor I pledge that I have not violated the provisions of the NJIT student integrity code as specified by <http://www.njit.edu/academics/pdf/academic-integrity-code.pdf>

Signature: _____

_____ DO NOT WRITE BELOW THIS LINE _____

PART A: _____ (100)

PART B: _____ (35)

PART C: #1 _____ (20)

#2 _____ (20)

TOTAL SCORE: _____

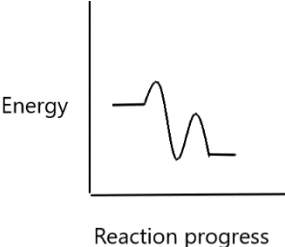
Part A: 20 multiple choice questions worth 5 points each for a total of 100 points. The periodic table at the end of the exam has a lot of information. Please refer to it as needed.

1. Consider the reaction: $AB_{(g)} \rightarrow A_{(g)} + B_{(g)}$. Which of these could be an expression for the rate law?
 - a. Rate = $k[A]$
 - b. Rate = $k[B]$
 - c. Rate = $k[A][B]$
 - d. Rate = $k[AB]$
 - e. All of these could be expressions for the rate law

2. Consider the reaction: $A_4(g) + 6B_2(g) \rightarrow 4AB_3(g)$. At a certain instant the initial rate of disappearance of B_2 is 0.5 M/s. What is the value of the appearance of AB_3 at the same instant?
 - a. 0.75 M/s
 - b. 1.5 M/s
 - c. 0.11 M/s
 - d. 0.33 M/s
 - e. 0.65 M/s

3. For the reaction: $X_{(g)} + Y \rightarrow XY_{(g)}$ The rate law is given by the expression, Rate = $k[Y]^3$. How does the rate change when the $[Y]$ is tripled?
 - a. The rate is tripled
 - b. The rate is doubled
 - c. The rate is 6 times the original rate
 - d. The rate is 9 times the original rate
 - e. The rate is 27 times the original rate

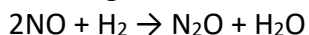
4. Consider the reaction $2H_2 + O_2 \rightarrow H_2O$. The concentration of hydrogen changed from 0.90 M to 0.60M in 30. seconds. What is the rate of the reaction?
 - a. 1.0 Ms^{-1}
 - b. 0.01 Ms^{-1}
 - c. 0.02 Ms^{-1}
 - d. 0.0050 Ms^{-1}
 - e. 0.50 Ms^{-1}

5. Which of the following is **TRUE** for a reaction $A \leftrightarrow B$
- A catalyst is present at the beginning and the end of the reaction
 - A catalyst lowers the activation energy of the reverse reaction only
 - A catalyst has no effect on the rate of the reaction
 - A catalyst gets consumed during the course of reaction
 - A catalyst lowers the activation energy of only the forward reaction only
6. For the reaction: $2\text{MnO}_4^- + 5\text{H}_2\text{C}_2\text{O}_4 + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}$, the following rate law was obtained experimentally: $\text{Rate} = k[\text{MnO}_4^-]^2[\text{H}_2\text{C}_2\text{O}_4]$. What is the overall order of the reaction?
- 2
 - 3
 - 1
 - 4
 - Cannot determine
7. The energy diagram below represents the steps in a chemical reaction. Based on the diagram what can you comment about the reaction mechanism?
- 
- i) The second step in the mechanism has a higher activation energy
- ii) The first step in the mechanism has a higher activation energy
- iii) The first step is the rate determining step
- iv) The second step is the rate determining step
- i and iii
 - ii and iii
 - i and iv
 - ii and iv
 - cannot determine from graph
8. Consider the balanced equation $2A + 5B \rightarrow 3C + D$. Given an excess of A, what is the maximum amount of C that can be made from 3.0 moles of B?
- 7.5 mol
 - 5.0 mol
 - 0.60 mol
 - 1.7 mol
 - 1.80 mol

9. The catalytic hydrogenation of ethylene (C_2H_4) in the presence of a Palladium catalyst is a zero order reaction. Which of the following is an accurate statement(s)?

- a. the rate of the reaction increases with $[\text{C}_2\text{H}_4]$
- b. the rate of the reaction decreases with $[\text{C}_2\text{H}_4]$
- c. the rate is independent of $[\text{C}_2\text{H}_4]$
- d. the rate of the reaction is 0 m/s
- e. None of the above

10. The following two observations were made for the reaction between nitric oxide and hydrogen:



1) The plot of $1/[\text{NO}]$ versus time (t) gave a straight line

2) The plot of $\ln[\text{H}_2]$ versus time (t) gave a straight line

Which rate law is consistent with this observation?

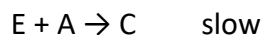
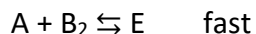
- a. $\text{Rate} = k [\text{NO}][\text{H}_2]$
- b. $\text{Rate} = k[\text{NO}]^2[\text{H}_2]$
- c. $\text{Rate} = k[\text{NO}]^2[\text{H}_2]^2$
- d. $\text{Rate} = k[\text{NO}][\text{H}_2]^2$
- e. $\text{Rate} = k[\text{NO}]^2$

11. The half-life of a chemical reaction $\text{M} \rightarrow \text{S}$ does not change as time progresses. Which of the following statements are correct?

- i) the reaction is first order in M
 - ii) the reaction is not first order in M
 - iii) the half-life depends on the initial concentration of M
 - iv) the half-life of the reaction is independent of the initial concentration
- a. i and ii
 - b. ii and iii
 - c. ii and iv
 - d. i and iv
 - e. i and iii

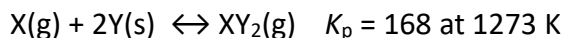
12. The following mechanism is proposed for the reaction: $2\text{A} + \text{B}_2 \rightarrow \text{C}$

Which of the following rate laws is consistent with this mechanism?



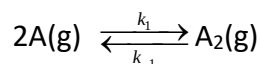
- a. $\text{Rate} = k[\text{A}]^2[\text{B}_2]$
- b. $\text{Rate} = k[\text{A}]^2[\text{B}_2]^2$
- c. $\text{Rate} = k[\text{A}][\text{B}_2]^2$
- d. $\text{Rate} = k[\text{A}][\text{B}_2]$
- e. Cannot determine with the information provided

13. Which of the following statements is **TRUE** regarding the following reaction at equilibrium?



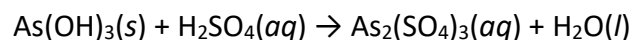
- a. Adding more $X_{(g)}$ will have no effect on the production of XY_2
- b. The value of the equilibrium constant K_p is a constant at all temperatures
- c. Since the system is at equilibrium, $[X] = [Y]$
- d. Since $K_p \gg 1$, there will be more reactants than products at equilibrium
- e. Adding more $Y_{(s)}$ will not result in the production of more XY_2

14. What can you say about the equilibrium condition for the elementary reaction with the information provided?



- a. $[A] = [A_2]$
- b. $k_1[A]^2 = k_{-1}[A_2]$
- c. $[A] > [A_2]$
- d. $[A] < [A_2]$
- e. None of the above

15. What is the coefficient for water when the following equation is balanced?



- a. 1
- b. 2
- c. 6
- d. 8
- e. 10

16. If $K_{eq} = 0.121$ for $A_2 + 2B \rightleftharpoons 2AB$, then for $4AB \rightleftharpoons 2A_2 + 4B$, K'_{eq} would equal

- a. 0.242
- b. 0.121
- c. 0.331
- d. 4.13
- e. 68.3

17. For which of the following reaction will $K_p = K_c$?

- a. $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$
- b. $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(l)}$
- c. $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$
- d. $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$
- e. $2CaO_{(s)} + CO_{2(s)} \rightleftharpoons 2CaCO_{3(s)}$

18. Consider the following **endothermic** reaction at equilibrium: $2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$. What are conditions that will favor the maximum production of B_2 ?

- a. Low temperature and low pressure
- b. Low temperature and high pressure
- c. High temperature and high pressure
- d. High temperature and low pressure
- e. None of the above

19. Consider the following reaction: $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$ ($K = 1.00 \times 10^{-2}$)

Given 1.00 mole of $HF(g)$, 0.362 mole of $H_2(g)$, and 0.750 mole of $F_2(g)$ are mixed in a 6.00 L flask, determine the reaction quotient, Q .

- a. $Q = 3.68$, reaction goes to the left
- b. $Q = 3.68$, reaction goes to the right
- c. $Q = 0.27$, reaction goes to the left
- d. $Q = 0.27$, reaction goes to the right
- e. $Q = K$, system is at equilibrium

20. For the reaction, $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ at 750°C , express K_c in terms of K_p .

$K_c =$

- a. $K_p (RT)$
- b. $K_p / (RT)$
- c. K_p
- d. $K_p (RT)^2$
- e. $K_p / (RT)^2$

Part B: Five questions worth 35 points. Enter your choice in the Scantron provided.

21. A reaction is followed and found to have a rate constant of $3.36 \times 10^4 \text{ M}^{-1}\text{s}^{-1}$ at 344 K. and a rate constant of $7.69 \text{ M}^{-1}\text{s}^{-1}$ at 219 K. Determine the activation energy for this reaction

- a. 11.5 kJ/mol
- b. 28.8 kJ/mol
- c. 42.0 kJ/mol
- d. 58.2 kJ/mol
- e. 12.5 kJ/mol

22. For a reaction in which A and B react to form C, the following initial rate data were obtained:

[A] (mol/L)	[B] (mol/L)	Initial Rate of Formation of C (mol/L·s)
0.10	0.10	1.00
0.10	0.20	4.00
0.20	0.20	8.00

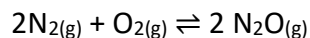
- a. Rate = $k[A]^3$
- b. Rate = $k[A]^2[B]$
- c. Rate = $k[A][B]^2$
- d. Rate = $k[B]^3$
- e. Rate = $k[A]^2[B]^2$

23. The reaction $A \rightarrow B + C$ is known to be zero order in A with a rate constant of $5.0 \times 10^{-2} \text{ mol/L}\cdot\text{s}$ at 25°C . An experiment was run at 25°C where $[A]_0 = 1.0 \times 10^{-3} \text{ M}$. What will be the concentration of B after $5 \times 10^{-3} \text{ sec}$?

- a. $5 \times 10^{-5} \text{ M}$
- b. $5 \times 10^{-4} \text{ M}$
- c. $2.5 \times 10^{-4} \text{ M}$
- d. $1.5 \times 10^{-5} \text{ M}$
- e. $7.5 \times 10^{-4} \text{ M}$

24. Determine the value of K_c for the following reaction if the equilibrium concentrations are as follows:

$$[\text{N}_2]_{\text{eq}} = 3.6 \text{ M}, [\text{O}_2]_{\text{eq}} = 4.1 \text{ M}, [\text{N}_2\text{O}]_{\text{eq}} = 3.3 \times 10^{-18} \text{ M}.$$



- a. 5.0×10^{36}
- b. 4.9×10^{-17}
- c. 2.2×10^{-19}
- d. 2.0×10^{-37}
- e. 4.5×10^{18}

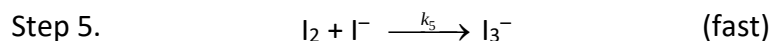
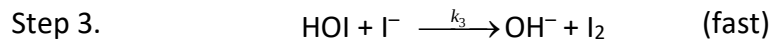
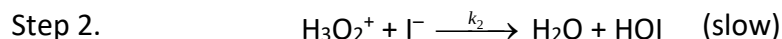
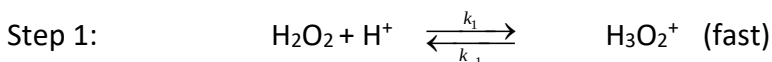
25. Consider the following equilibrated system: $2\text{NO}_2(g) \rightleftharpoons 2\text{NO}(g) + \text{O}_2(g)$. If the K_p value is 0.604, find the equilibrium pressure of the O_2 gas if the NO_2 gas pressure is 0.520 atm and the P_{NO} is 0.300 atm at equilibrium.

- a. 1.05 atm
- b. 24.8 atm
- c. 0.348 atm
- d. 0.201 atm
- e. 1.81 atm

Part B: Two questions with multiple parts worth 40 points. Show all your work to get full points

Question 1 A:

Under certain conditions the reaction $\text{H}_2\text{O}_2 + 3\text{I}^- + 2\text{H}^+ \rightarrow \text{I}_3^- + 2\text{H}_2\text{O}$ occurs by the following series of steps:



Write the overall rate law for the reaction based on the mechanism given: _____

Identify reactive intermediate(s) : _____

Question 1 B:

For the reaction given below, 2.00 moles of A and 3.00 moles of B are placed in a 6.00-L container.

$A(g) + 2B(g) \rightleftharpoons C(g)$. At equilibrium, the concentration of A is 0.213 mol/L. What is the value of K_{eq} ?

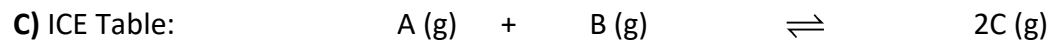
Question 2: There are several parts to this question. Answer all of them carefully.

For the exothermic reaction, $A(g) + B(g) \rightleftharpoons 2C(g)$, $K_p = 0.80$ performed in a sealed vessel,

The initial pressures are as follows: $P_A = 1.10$ atm; $P_B = 1.10$ atm and $P_C = 0.50$ atm. Once the system attains equilibrium, what are the equilibrium pressures of each species?

A) Expression for K_p :

B) Value of Q:



Initial:

Change:

Equilibrium:

D) Equilibrium pressures: $P_A (eq)$: _____

$P_B (eq)$: _____

$P_C (eq)$: _____

E) What is the total pressure in the system at equilibrium?

F) How will lowering the volume affect the equilibrium?

$$K_p = K_c (RT)^{\Delta n}$$

ABBREVIATIONS AND SYMBOLS				CONSTANTS	
amount of substance	n	Faraday constant	F	molar	M
ampere	A	free energy	G	molar mass	M_w
atmosphere	atm	frequency	ν	mole	mol
atomic mass unit	amu	gas constant	R	Planck's constant	h
atomic molar mass	A	gram	g	pressure	P
Avogadro constant	N_A	hour	h	rate constant	k
Celsius temperature	$^{\circ}\text{C}$	joule	J	reaction quotient	Q
centi- prefix	c	kelvin	K	second	s
coulomb	C	kilo- prefix	k	speed of light	c
electromotive force	E	liter	L	temperature, K	T
energy of activation	E_a	measure of pressure	mmHg	time	t
enthalpy	H	milli- prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K				

$R = 8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$R = 0.0821 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$R_H = 2.18 \times 10^{-18} \text{ J}$
$1 F = 96,500 \text{ C}\cdot\text{mol}^{-1}$
$1 F = 96,500 \text{ J}\cdot\text{V}^{-1}\cdot\text{mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$
$c = 2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
$K_w (@ 25^{\circ}\text{C}) = 1.00 \times 10^{-14}$
$0^{\circ}\text{C} = 273.15 \text{ K}$

EQUATIONS		
$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$	$E = E^\circ - \frac{RT}{nF} \ln Q$	Integrated Rate Laws
$\text{pH} = \text{pK}_a + \log\left(\frac{[\text{A}^-]}{[\text{HA}]}\right)$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	zero: $[A] = [A]_0 - kt$
$\Delta E_{H-\text{atom}} = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$	$\Delta G^\circ = -RT \ln K$	first: $\ln[A] = \ln[A]_0 - kt$
		second: $\frac{1}{[A]} = \frac{1}{[A]_0} + kt$

1 1A 1 H 1.008	2 2A 4 Be 9.012											13 3A 5 B 10.81	14 4A 6 C 12.01	15 5A 7 N 14.01	16 6A 8 O 16.00	17 7A 9 F 19.00	18 8A 2 He 4.003																																																																																																																												
3 Li 6.941	10 Ne 20.18	11 Na 22.99	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80																																																																																																																		
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3	55 Cs 132.9	56 Ba 137.3	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0																																																																																																											
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Uub (277)	113 Nh (284)	114 Uuq (279)	115 Uup (285)	116 Uuh (286)	117 Uus (287)	118 Uuo (288)	119 Uus (289)	120 Uuo (290)	121 Uut (291)	122 Uuq (292)	123 Uub (293)	124 Uuc (294)	125 Uud (295)	126 Uue (296)	127 Uuf (297)	128 Uug (298)	129 Uuh (299)	130 Uuo (300)	131 Uut (301)	132 Uuq (302)	133 Uub (303)	134 Uuc (304)	135 Uud (305)	136 Uue (306)	137 Uuf (307)	138 Uug (308)	139 Uuh (309)	140 Uuo (310)	141 Uut (311)	142 Uuq (312)	143 Uub (313)	144 Uuc (314)	145 Uud (315)	146 Uue (316)	147 Uuf (317)	148 Uug (318)	149 Uuh (319)	150 Uuo (320)	151 Uut (321)	152 Uuq (322)	153 Uub (323)	154 Uuc (324)	155 Uud (325)	156 Uue (326)	157 Uuf (327)	158 Uug (328)	159 Uuh (329)	160 Uuo (330)	161 Uut (331)	162 Uuq (332)	163 Uub (333)	164 Uuc (334)	165 Uud (335)	166 Uue (336)	167 Uuf (337)	168 Uug (338)	169 Uuh (339)	170 Uuo (340)	171 Uut (341)	172 Uuq (342)	173 Uub (343)	174 Uuc (344)	175 Uud (345)	176 Uue (346)	177 Uuf (347)	178 Uug (348)	179 Uuh (349)	180 Uuo (350)	181 Uut (351)	182 Uuq (352)	183 Uub (353)	184 Uuc (354)	185 Uud (355)	186 Uue (356)	187 Uuf (357)	188 Uug (358)	189 Uuh (359)	190 Uuo (360)	191 Uut (361)	192 Uuq (362)	193 Uub (363)	194 Uuc (364)	195 Uud (365)	196 Uue (366)	197 Uuf (367)	198 Uug (368)	199 Uuh (369)	200 Uuo (370)	201 Uut (371)	202 Uuq (372)	203 Uub (373)	204 Uuc (374)	205 Uud (375)	206 Uue (376)	207 Uuf (377)	208 Uug (378)	209 Uuh (379)	210 Uuo (380)	211 Uut (381)	212 Uuq (382)	213 Uub (383)	214 Uuc (384)	215 Uud (385)	216 Uue (386)	217 Uuf (387)	218 Uug (388)	219 Uuh (389)	220 Uuo (390)	221 Uut (391)	222 Uuq (392)	223 Uub (393)	224 Uuc (394)	225 Uud (395)	226 Uue (396)	227 Uuf (397)	228 Uug (398)	229 Uuh (399)	230 Uuo (400)	231 Uut (401)	232 Uuq (402)	233 Uub (403)	234 Uuc (404)	235 Uud (405)	236 Uue (406)	237 Uuf (407)	238 Uug (408)	239 Uuh (409)	240 Uuo (410)	241 Uut (411)	242 Uuq (412)